Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1154

Washington, D. C. ▼ April 30, 1923

FEEDING HABITS OF THE JAPANESE BEETLE[1] WHICH INFLUENCE ITS CONTROL.[2]

By LOREN B. SMITH, *Entomologist, Deciduous Fruit Insect Investigations, Bureau of Entomology.*

CONTENTS.

	Page.
Difficulty of controlling the Japanese beetle..	1
Feeding habits of the Japanese beetle.........	2
Movements of the beetles in relation to their food plants.........................	4
The process of infestation..................	4
Proportion of sexes on various types of food plants................................	5
Rate at which the beetles feed...............	7
Summary..................................	10

DIFFICULTY OF CONTROLLING THE JAPANESE BEETLE.

Serious difficulties have been encountered in attempting to control the Japanese beetle (*Popillia japonica* Newm.) by the application of poisonous materials to its food plants.[3] Observations made during the season of 1921 indicate that the habits of the beetle, together with its response to environmental conditions, account in a measure for the lack of success in previously conducted spraying operations. The importance of controlling this new pest makes it advisable to bring together certain available information relative to the habits of the beetle which may have a more or less direct bearing on its control by sprays.

With a phytophagous insect such as the Japanese beetle it is essential that an insecticide be obtained which will be eaten by the beetles and cause their death. While arsenical sprays, which in this case act as repellents, will protect certain crops from the attacks of the beetles, this does not solve the problem of keeping the insect in check by reducing its numbers, nor does it protect those crops which it is impracticable to spray either for mechanical reasons or because of likelihood of injuring the foliage. It has been observed that commercial lead arsenate applied to fruit or shade trees kills a small number of the beetles and greatly reduces or on occasion entirely prevents subsequent reinfestation. If adjacent unprotected crops are in a suitable condition for the beetles to feed upon, it is reasonable to suppose that the infestation of these would be somewhat increased owing to the fact that a portion of the normal feeding area of the beetles was rendered distasteful by the spray. The increase in degree of infestation might or might not be in proportion to the reduction in infestation on the sprayed foliage. The writer and other workers have noted that under conditions favorable for activity among the beetles the degree of infestation increases in a somewhat direct proportion to the number of beetles on the plant. In other words, there is a gregarious instinct which attracts the insects to plants on which other individuals of the same species are feeding. Since this beetle has a wide range of food plants, is an active and strong flier, and is decidedly gregarious, the need for detailed studies of its biological relationships is apparent.

---

[1] *Popillia japonica* Newm.

[2] Submitted for publication Dec, 12, 1922. The work reported herein was done at the Japanese Beetle Laboratory, Riverton, N. J., in cooperation with the department of agriculture of New Jersey. The writer desires to acknowledge the assistance of Harry H. Pratt on this project during the season of 1921. Credit is also due B. R. Leach, who has been in charge of the insecticidal investigations at the Japanese Beetle Laboratory for several years, and whose work on the chemical phases of the problem led to the biological studies of which this is a part.

[3] Davis, J. J. *In* Jour. of Econ. Ent., v. 13, p. 188. April, 1920.

FEEDING HABITS OF THE JAPANESE BEETLE.

Regarding its food habits, the Japanese beetle may properly be termed polyphagous, having been recorded as attacking 210 species of plants, which are distributed among 59 families. In the past certain species more than others have been injured by the beetles. Among the cultivated crops may be mentioned apple (*Pyrus malus*), peach (*Amygdalus persica*), grape (*Vitis* spp.), cherry (*Prunus* spp.), corn (*Zea mays*), and string bean (*Phaseolus vulgaris*). Shade trees, such as elm (*Ulmus* spp.), oak (*Quercus* spp.), and willow (*Salix* spp.), are usually preferred food plants, while smartweed (*Polygonum* spp.), evening primrose (*Oenothera biennis*), sassafras (*Sassafras sassafras*), and elder (*Sambucus canadensis*) represent the herbaceous plants and shrubs. The beetles do not feed consistently on plants of any one type, hence a general statement that one particular species is preferred can not be made. Almost no plants, excepting certain conifers, are exempt from attack between June and November when the beetles are present. At times they will be found abundantly on low-growing plants such as alsike clover (*Trifolium hybridum*), white clover (*T. repens*), violet (*Viola* spp.), or galinsoga (*Galinsoga* spp.), or they may feed on the taller shade trees. It was first believed that the succulency of the leaves influenced the insects to a great extent in the selection of their food plants. Later observations indicate that this in itself is not the determining factor in the apparent preference shown for certain species. During the period between June 18 and June 30, 1921, a 2-year-old peach orchard became infested and the foliage on the mature wood was eaten first; in all about 30 per cent of the leaves were injured by the feeding of the insects. Between the 8th and the 12th of July, when the abundance of the beetles was at its height, they left these peach trees for other food plants. These particular peach trees were not reinfested during the season, although a sour cherry orchard adjacent to the peaches was more or less heavily infested from June to October. Similar facts were noted in a bearing peach orchard about 100 yards from the young orchard mentioned, except that the beetles did not leave until August.

A large patch of smartweed, near the center of the area in which this insect is most abundant, became infested June 17, 1921. By July 1 hundreds of beetles were present on the plants each day. On

July 10 it was noted that the beetles were less abundant, although there was still plenty of foliage upon which they could feed. By July 12 only 6 beetles were left on this particular patch of smartweed; 5 of these were males and 1 a female. Thereafter the infestation noted on these plants was as follows: July 13, 2 males; July 14, 7 males; July 15, none; July 16, none; July 19, at 9 a. m., 3 males, at 3.30 p. m., 7 males; July 20, at 9.30 a. m., 3 females and 10 males, at 11.30 a. m., 12 females and 22 males, and by 2 p. m. the plants were heavily infested. One hundred and twenty beetles were collected at random from these plants, and of these 52 were females and 68 males. This patch of smartweed remained infested until after September 15. Similar instances were noted on sassafras and on Yellow Transparent apples.

The beetles are strongly attracted to ripening fruit, and early apples and peaches may suffer severe injury from the depredations of the insects. So numerous do the beetles become at times that individual fruits, especially where they have ripened prematurely, will be completely covered by a swarming mass of the insects. It has also been noted that the foliage of those varieties which ripen early in the season is more severely injured than that of the so-called late varieties. It is possible that this may be due in a measure to the attraction of the beetles by the color of the fruit rather than to a preference for the foliage of the early varieties. This is indicated by the fact that the insects are gregarious and usually will alight on those plants where beetles are already present. No apples have been observed to be severely attacked early in the season and it is only after some of the fruits have partially ripened, either prematurely through disease or otherwise, that the heavy infestations of apples occur. Peaches affected with brown-rot, caused by *Sclerotinia fructigena* (Pers.) Schr., are particularly attractive to the beetles. It is probable that later experiments will show that these insects may cause serious losses through the dissemination of this fungus from diseased to healthy fruit.

Throughout the season when the beetles are present they may be found at any time on a large number of plant species. In general, however, during the season of 1921 the beetles showed a tendency to be more abundant on weeds, sassafras, elder, sweet cherries, and grapes during the early part of the season. By midsummer fruit and shade trees were more heavily infested, while during August and September heavy infestations were confined to corn, beans, clover, and various plants in bloom at that time. The developing ears of corn were particularly attractive to the beetles and as many as 27 beetles were taken from a single ear.

Moore and Cole have shown [4] that the beetles are positively phototropic and their results are borne out by the fact that on apples, cherries, grapes, and shade trees most of the feeding is done on the foliage which is exposed to the direct rays of the sun. The beetles rarely feed early in the season on the peach leaves borne on new wood. As the season progresses, however, they feed more or less generally on the mature foliage. It is of interest to note that on the majority of their food plants the beetles feed on the upper surface of the leaves, but on peaches they often feed from the under side.

---

[4] Moore, A. R., and Cole, W. H. The response of *Popillia japonica* to light and the Weber-Fechner law. *In* Jour. Gen. Physiology, v. 3, no. 3, p. 331-335, fig. 1. 1921.

MOVEMENTS OF THE BEETLES IN RELATION TO THEIR FOOD PLANTS.

Moore and Cole[5] state that "below 23° C. the beetles are generally inactive; 38–39° C. is optimum for their activity, while above 40° C., injurious effects are apparent. At 45° C. activity ceases quickly and permanently. Under the ruby light and in the dark most of the beetles become quiet."

These observations are substantiated by the general increase in activity of the beetles during the day until 2 or 3 p. m., after which their activity decreases until dark, when flight ceases. The females deposit their eggs in the soil, and the egg-laying period extends over a period of from two to four weeks. In a large majority of cases the females enter the soil late in the afternoon and remain there until the following morning. During this time they deposit from 1 to 5 eggs. In cages females occasionally remained in the soil for 2, 3, or in some cases 4 days, although a large number of individuals usually spent 10 to 15 hours out of the 24 hours in the soil, and during this time an average number of 3 eggs were laid. Nearly all the females under observation entered the soil late in the day, although in many cases eggs were laid only every third or fourth night. This is evidently what occurs under natural conditions, since numerous collections show that the proportion of females to males on the food plants is lowest between 7 p. m. and 7 a. m. Mating may occur several times each day throughout the egg-laying period. There is a distinct movement of the males toward those plants on which the females are feeding. On clear days, between 8 and 9 a. m., numerous males can be observed flying low over the ground in search of emerging females. During the early part of the day this tends to concentrate the beetles on low-growing plants such as smartweed, beans, and various weeds.

THE PROCESS OF INFESTATION.

Mating and feeding more or less intermittently, there is a considerable movement of the beetles from plant to plant during the day. A female beetle on a plant will quickly attract many males, and, owing to the gregarious nature of this species, other females as well. As has been stated, the males become active and are flying in the morning before the majority of the females have emerged from the soil. During this period the male beetles feed erratically and for short periods on a large variety of plants.

Later in the day, as the number of females in flight increases, the males usually select a plant on which one or more beetles are present. Between July 10 and July 20 observations were made on five 2-year-old peach trees, 3 grapevines, 5 small sour cherry trees, 1 sassafras shrub, 5 plants of field corn, and 1 apple tree. Without disturbing the insects, the sex of the first 10 beetles to arrive on the plants was noted. When the observations were begun, the plants were uninfested. After becoming infested, the plants on which these observations were made remained infested throughout the day, and the beetles included in the following data represent the first 10 of an infestation which lasted at least one day:

---

[5] Op. cit., p. 331.

TABLE 1.—*Sex of the first 10 Japanese beetles (Popillia japonica) to infest food plants between 7.45 and 9 a. m., July 10 to 20, 1921, Riverton, N. J.*

Food plants.	Sex of first 10 beetles to arrive.										Number of females.
	1	2	3	4	5	6	7	8	9	10	
Peach	♂	♂	♀	♂	♀	♂	♂	♀	♂	♂	3
Do	♂	♀	♂	♂	♀	♀	♂	♂	♂	♀	4
Do	♀	♂	♂	♀	♂	♀	♀	♂	♂	♂	4
Do	♂	♂	♀	♀	♀	♂	♂	♂	♀	♂	4
Do	♂	♂	♂	♂	♂	♂	♀	♂	♀	♂	2
Sour cherry	♂	♂	♂	♂	♂	♂	♂	♂	♀	♀	2
Do	♂	♀	♂	♀	♀	♂	♂	♀	♀	♂	5
Do	♀	♀	♂	♂	♂	♂	♂	♀	♂	♂	3
Do	♂	♂	♂	♂	♀	♀	♂	♂	♂	♀	3
Do	♂	♀	♂	♂	♀	♂	♂	♀	♀	♂	4
Sassafras	♂	♀	♂	♀	♀	♂	♂	♀	♀	♂	5
Corn	♂	♀	♂	♂	♀	♂	♂	♀	♂	♂	3
Do	♂	♂	♀	♀	♂	♂	♀	♀	♂	♀	5
Do	♂	♂	♂	♂	♀	♂	♂	♂	♀	♂	2
Do	♂	♂	♂	♀	♂	♂	♂	♂	♀	♂	2
Do	♂	♀	♂	♂	♂	♂	♂	♀	♀	♂	3
Grape	♂	♂	♀	♂	♂	♀	♂	♂	♂	♀	3
Do	♀	♂	♀	♂	♂	♀	♂	♂	♂	♀	4
Do	♂	♀	♂	♂	♀	♀	♂	♂	♀	♂	4
Apple	♂	♂	♂	♂	♂	♂	♀	♂	♀	♂	2
Total females	3	8	5	6	10	6	4	8	11	6	67
Per cent females	15	40	25	30	50	30	20	40	55	30	33.5

There were only three females among the first beetles to arrive on the 20 different plants under observation. Of the second beetles to arrive on the plants, 8, or 40 per cent, were females. Of the third beetles, 25 per cent were females. The proportion of females among the 4, 5, 6, 7, 8, 9, and 10 beetles was 30, 50, 30, 20, 40, 55, and 30 per cent, respectively. There were not less than 2 or more than 5 females among the first 10 to arrive on any one plant. Data reported under the next heading indicate that the percentage of female beetles on similar plants during the hours when these observations were made is between 20 and 30 per cent. Therefore, the chances are about 1 to 4 or 5 that, on a numerical basis, female beetles will be the first to infest or reinfest a food plant. On the basis of the data collected, one sex is as likely as the other to begin a new infestation, providing there are equal numbers of both sexes flying at the time.

PROPORTION OF SEXES ON VARIOUS TYPES OF FOOD PLANTS.

Collections of beetles were made in July and August at hourly intervals during the day from several different food plants. Apple trees were selected as representing the taller type of plants; corn, grapes, and althea or rose of Sharon (*Hibiscus syriacus*), those of medium height; and smartweed, evening primrose, mercury weed, and the velvet-leaved mallow, those with low-growing habits. A collection of between 100 and 125 beetles was made at random from the plants at each hour. The collections were kept in separate bottles and were later sorted and the sex determined. Figures 1, 2, and 3 illustrate graphically the percentages of female beetles obtained in these collections.

In Figure 1 are shown the percentages of female beetles in two series of hourly collections between 7 a. m. and 8 p. m. from smartweed and other low-growing plants. These collections were made August 18 to 24, 1921. Between 7 and 10 o'clock in the morning the females constitute between 20 and 32 per cent of the beetles present on the plants. There is a gradual increase in the percentage of females until it reaches nearly 40 per cent in the 1 o'clock collection. This proportion is not increased, nor does it fall below 30 per cent until after 6 p. m. In the evening the females constitute about 25 per cent of the beetles on the plants, which is nearly the same proportion found early in the morning.

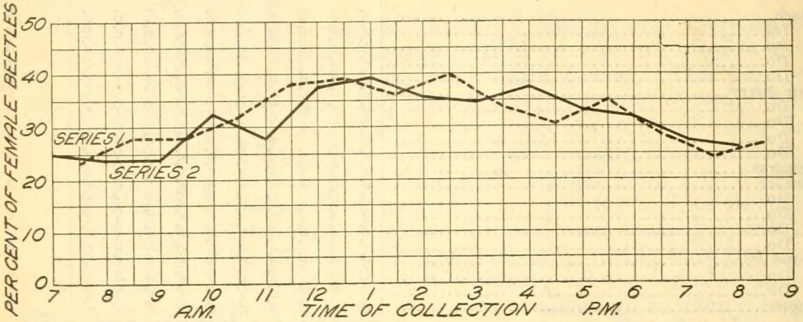

Fig. 1.—Per cent of female beetles in collections of Japanese beetles from smartweed, mercury weed, evening primrose, and mallow, August 18 to 24, 1921, at Riverton, N. J.

In Figure 2 are shown the percentages of females in two series of collections, one of which was made from field corn July 18, and the other from grape and althea between August 22 and August 24, 1921. In the collections made from corn before 8 a. m. and after 6 p. m. the females constituted less than 20 per cent of the total number of beetles. Between 11 a. m. and 1 p. m. the proportion of females to males was highest. In the 11 o'clock and 1 o'clock collections over 40 per cent of the beetles were females. On grapes the percentage of the beetles which were females is less than 20 per cent in the collection made before 9 a. m. and after 6 p. m., and it varies between 30 and 40 per cent in the collections made between 10 a. m. and 4 p. m.

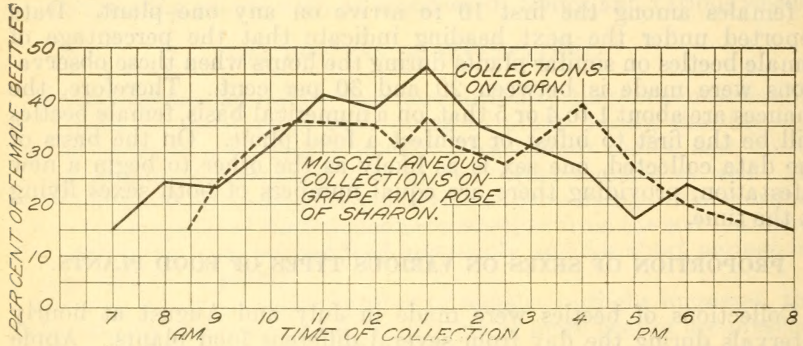

Fig. 2.—Per cent of female beetles in collections of Japanese beetles from corn, July 18, and from grape and rose of Sharon, August 22 to 24, 1921, at Riverton, N. J.

Figure 3 is a graphic representation of the percentages of females in two series of collections made from Yellow Transparent apple trees July 18, 1921. The two curves follow much the same course and can be considered together. The first collection was made at 5 a. m. and the last at 9 p. m. (though the curve ends with the 7 o'clock collection). Until after 8 a. m. less than 20 per cent of the beetles collected were females. During the forenoon there is a decided increase in the proportion of females collected. Between 10.30 a. m. and 2 p. m. from 40 to 47 per cent of the beetles collected were females. From 2 to 4 o'clock the percentage of females decreases to about 20 per cent. Only 15 to 20 per cent of the beetles collected between 5 and 9 p. m. were females.

Tall-growing herbaceous plants, shrubs, and trees are much less heavily infested with the beetles between 4 p. m. and 9 a. m. than they are during the middle of the day. From the data presented in Figures 1, 2, and 3 it is evident that toward evening there is a more or less definite movement of the female beetles from the tall to the low growing food plants, and also to the ground for the deposition of their eggs. It is also to be noted that low-growing plants such as smartweed maintain a higher proportion of females to males throughout the day than do the taller shrubs and trees. As the females move from the tall to the low growing species there is a complementary movement of the male beetles to the lower-growing plants. This change of location by the males is much less definite and complete than that of the females. However, in making hourly collections of 100 or more beetles it was found that it was often difficult to collect the required quota on apples and grapes in the early morning and late evening, while at midday thousands could have been collected on the same plants. These daily movements of the beetles may in a measure account for the fact that certain plants or groups of plants may be heavily infested for a period of time and then become free from the infestation, which in some cases does not recur during the season.

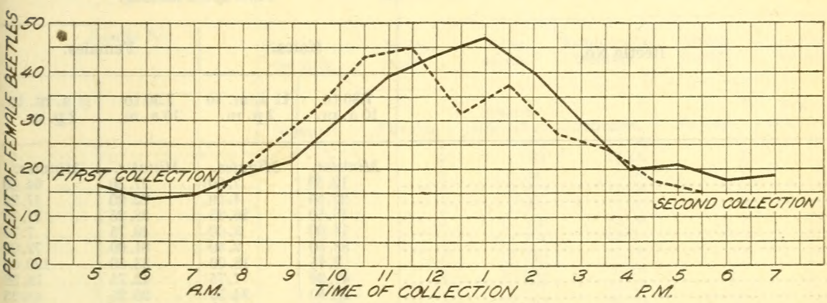

FIG. 3.—Per cent of female beetles in collections of Japanese beetles from Yellow Transparent apple, July 18, 1921, at Riverton, N. J.

RATE AT WHICH THE BEETLES FEED.

Observations were made for the purpose of determining the average length of time which the beetles spent in feeding on various plants and also the rate at which they consumed the foliage. During a period between July 18 and 23, 1921, 25 males and 25 females were timed and the length of the feeding periods noted between the hours of 7.30 and 10 a. m. on apple foliage. Similar observations were made between the hours of 11 a. m. and 2 p. m. Table 2 gives the data thus obtained. From these data it was found that under conditions favorable for movement and activity among the beetles the average length of time which the male beetle fed was 21.65 minutes between the hours of 7.30 and 10 a. m. During the same period the females fed for an average period of 40.24 minutes. In the second series of observations, between 11 a. m. and 2 p. m., the males fed for an average period of 23.3 minutes and the females 46 minutes before flying to other food plants.

TABLE 2.—*Length of time beetles of Popillia japonica spent feeding on apple foliage between 7.30 and 10 a. m., and between 11 a. m. and 2 p. m., July, 1921, Riverton, N. J.*

Beetle No.	Time spent feeding.			
	Males.		Females.	
	7.30 to 10 a. m.	11 a. m. to 2 p. m.	7.30 to 10 a. m.	11 a. m. to 2 p. m.
	Minutes.	*Minutes.*	*Minutes.*	*Minutes.*
1	12.50	7.00	27.50	64.50
2	22.55	4.50	22.00	47.25
3	16.50	26.25	38.25	21.75
4	14.00	3.00	49.75	7.75
5	33.50	2.50	81.00	72.00
6	2.75	18.00	33.50	120.00
7	41.50	7.75	42.75	18.50
8	28.50	34.50	26.25	48.25
9	28.00	16.25	76.50	39.50
10	32.00	11.25	43.50	67.50
11	19.25	39.25	32.25	34.25
12	52.25	21.00	29.00	22.75
13	11.25	5.50	86.25	14.75
14	6.00	14.75	54.00	43.50
15	2.75	13.25	40.00	52.25
16	27.00	49.50	14.25	31.25
17	18.50	27.50	71.50	29.50
18	23.50	101.75	70.50	88.25
19	28.00	22.00	19.00	63.25
20	34.25	63.25	27.75	99.00
21	38.00	42.00	10.00	21.50
22	18.25	11.50	36.75	36.50
23	10.00	20.50	26.00	42.00
24	14.75	3.00	8.25	34.25
25	6.00	16.50	39.25	30.00
Total	541.25	582.25	1,005.75	1,150.00
Average time each beetle spent feeding	21.65	23.29	40.24	46.00

Observations were also made relative to the length of the feeding period of the beetles on grapes between the hours of 12.15 and 4 p. m. The data were collected from 25 beetles of each sex. They indicate that on grapes the average length of time the males spent in feeding was 21.54 minutes, while the females fed for an average time of 40.18 minutes. On July 29 the weather was cloudy, with a misty rain falling all day, and observations were made relative to the length of the feeding period on the foliage of sour cherries. Under these conditions the majority of the beetles were not feeding, although they remained on the foliage throughout the period of observation. The feeding was so erratic and of such small amount that no attempt was made to determine the actual time spent by the beetles in this way.

Data were collected relative to the rate at which beetles feed on apple. These are summarized in Table 3. It was found that under clear and warm weather conditions 20 male beetles feeding for an average time of 15.6 minutes each consumed 10.448 square millimeters of foliage. This was at the rate of 40.18 square millimeters an hour for each beetle. The females feeding on an average 25.05 minutes consumed 18.133 square millimeters of foliage, which amounted to 43.52 square millimeters an hour for each individual. It was noticeable that the females made a larger number of feeding holes in the leaves than the males and the holes made by the former averaged 2.01 square millimeters in area while those made by the males were on an average 2.6 square millimeters in area.

TABLE 3.—*Area eaten by beetles of Popillia japonica during clear weather while feeding on Yellow Transparent apple, July, 1921, Riverton, N. J.*

Beetle No.	Males.			Females.		
	Time spent feeding.	Holes made.	Area eaten.	Time spent feeding.	Holes made.	Area eaten.
	Minutes.	*Number.*	*Square millimeters.*	*Minutes.*	*Number.*	*Square millimeters.*
1	5.75	1	3.002	15.00	5	16.057
2	3.50	1	1.079	17.00	5	14.295
3	10.00	3	6.297	9.50	2	7.679
4	18.75	7	9.812	18.00	4	10.672
5	3.00	2	1.216	11.50	5	5.347
6	24.00	10	13.166	25.00	9	13.568
7	22.50	5	14.224	66.75	14	52.372
8	28.50	8	19.340	37.00	13	28.671
9	34.00	8	17.622	18.00	11	12.778
10	9.00	2	5.321	33.75	14	11.639
11	18.25	2	12.165	26.00	10	13.928
12	22.00	7	17.242	29.25	10	20.954
13	26.25	7	20.721	21.00	12	11.785
14	5.00	1	3.015	17.25	11	12.727
15	8.00	1	7.270	16.00	6	14.736
16	9.50	1	7.639	7.00	1	7.110
17	11.00	3	8.352	2.00	1	3.327
18	12.00	1	11.334	45.50	17	41.635
19	21.25	9	14.622	47.50	15	38.868
20	20.00	6	15.522	38.00	15	24.511
Total	312.25	85	208.961	501.00	180	362.659
Average	15.61	4.25	10.448	25.05	9	18.133
Rate per hour	40.18 square millimeters 0.062 square inch.			Rate per hour... 43.519 square millimeters. 0.067 square inch.		

Experiments to determine the rate of feeding of the beetles were also conducted in the insectary. On smartweed, under conditions favorable for the activity of the insects, it was found that the males fed at the rate of 29.99 square millimeters each hour while in the same length of time the females consumed on an average 40.56 square millimeters of foliage. On sour cherry foliage during the midday hours the rate of feeding was 10.8 square millimeters an hour by the males and 9.48 square millimeters by the females.

The data thus far collected indicate that the females feed somewhat longer on a plant before leaving than the males. The amount of foliage consumed by females in a given length of time is slightly greater than by the males. The rate of food consumption and the time spent by the insects in feeding on their various food plants during the day are undoubtedly greatly influenced and probably largely controlled by the weather conditions prevailing at the time. This, together with the fact that the species is undergoing a period of seasonal change and readjustment brought about by its new environmental conditions and its increasing numerical concentration, renders the problem of its control by sprays one of considerable difficulty. This applies not only to the chemical aspect of the insecticidal investigations necessary for a successful culmination of the work but also to the biological phases of the problem as well.

SUMMARY.

The control of the Japanese beetle has been handicapped by the fact that when the arsenicals used in commercial practice have been applied to the food plants of this insect only a small number of the beetles have been killed. Usually the infestation of the beetles on the sprayed plants is greatly reduced and reinfestation may be entirely prevented. This condition, together with the gregarious habits of the beetles, tends to concentrate the insects on plants which for economic reasons it is difficult to protect by sprays.

This insect has been recorded as attacking 210 species of plants. The most severe injury is confined to between 20 and 25 species, including most of the cultivated fruit trees, corn, and beans, besides various shade trees and ornamental shrubs.

The degree of infestation on the food plants is variable. Instances were noted on peach, smartweed, sassafras, and apple where the plants were heavily infested for a while, after which the beetles left for other food plants; in some cases the plants were not again infested during the season.

Ripening fruit of any kind, silk and ears of corn, and peaches affected with brown rot are particularly attractive to the beetles. So numerous do the insects become at times that prematurely ripened peaches and apples are completely covered with a swarming mass of beetles.

During the early part of the season the beetles are more abundant on weeds, cherries, and grapes; by midsummer, fruit and shade trees are more heavily infested, while during August and September heavy infestations are mostly confined to corn, beans, clover, and various plants in bloom at that time.

Most of the feeding occurs on the upper and outer foliage of the various food plants, especially where they are exposed to the direct rays of the sun.

Other workers have found that the greatest activity among the beetles occurred at 38° to 39° C. The observations of the writer showed that there is a general increase in the activity of the beetles until 2 or 3 p. m., after which time their activity decreases until dark, when flight ceases.

In a majority of cases the females enter the soil late in the afternoon, deposit from 1 to 4 or 5 eggs, and emerge the following morning to feed and mate. Some females may remain three or four days in the soil before they emerge again to feed. In many cases, however, eggs are laid only every third or fourth night.

There is a distinct movement of the male beetles to those plants on which females are feeding, and during the early part of the day the beetles tend to concentrate on low-growing plants such as smartweed and beans.

As the heat increases during the day the beetles become more active and disperse to taller plants until the early afternoon period, when they may be abundant on the tallest elms, oaks, and maples. After 3 o'clock their flight is toward the ground and to lower-growing plants.

One sex is as likely as the other to begin a new infestation, providing there are equal numbers of both sexes flying at the time.

Hourly and half-hourly collections of adults from several food plants showed the proportion of females to males was highest between 12 noon and 2 p. m. and lowest between 7 p. m. and 7 a. m. The taller plants, such as apple, showed the most marked differences in the proportion of the sexes at different times, while low-growing species, such as smartweed, showed the least. This indicates that many females leaving the taller trees may not enter the soil, but remain on low weeds during the night.

The average length of the feeding period of the beetles on apple foliage between the hours of 7.30 and 10 a. m., as observed in this study, was 21.65 minutes for the males and 40.24 minutes for the females. During the period 11 a. m. to 2 p. m., the males fed on an average 23.3 minutes and the females 46 minutes. The average length of the feeding period was noted during the afternoon on grapes. In this case it was found that the males fed on an average 21.54 minutes, while the females fed for 40.18 minutes. On rainy days the beetles are more or less inactive and less feeding occurs than on warm, clear days.

Data were collected relative to the rate at which the beetles feed. It was found that on apple the males fed at the rate of 40.18 square millimeters an hour, whereas the females consumed foliage at the rate of 43.519 square millimeters an hour.

ORGANIZATION OF THE U. S. DEPARTMENT OF AGRICULTURE.

Secretary of Agriculture	HENRY C. WALLACE.
Assistant Secretary	C. W. PUGSLEY.
Director of Scientific Work	E. D. BALL.
Director of Regulatory Work	
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	HENRY C. TAYLOR, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	WALTER G. CAMPBELL, *Acting Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Division of Accounts and Disbursements	A. ZAPPONE, *Chief.*
Division of Publications	EDWIN C. POWELL, *Acting Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
States Relations Service	A. C. TRUE, *Director.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	CHESTER MORRILL, *Assistant to the Secretary.*
Grain Future Trading Act Administration	
Office of the Solicitor	R. W. WILLIAMS, *Solicitor.*

This bulletin is a contribution from

Bureau of Entomology	L. O. HOWARD, *Chief.*
Fruit Insect Investigations	A. L. QUAINTANCE, *Entomologist in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

PURCHASER AGREES NOT TO RESELL OR DISTRIBUTE THIS
COPY FOR PROFIT.—PUB. RES. 57, APPROVED MAY 11, 1922.

▽